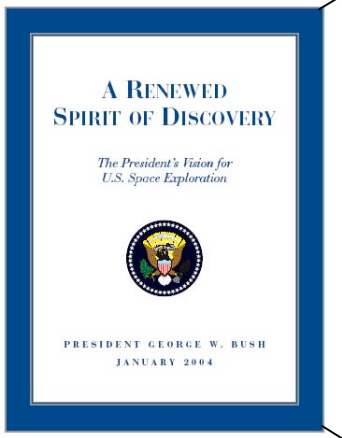

Exploration Systems Mission Directorate
Exploration Systems
Research & Technology
for Space Transportation
Presentation to the
NASA Exploration Transportation System Strategic Roadmap Committee
3-4 February 2005
Exploration Systems Research & Technology Office
NASA Exploration Systems Mission Directorate

Policy Context

Vision for U.S. Space Exploration (January 2004)

THE FUNDAMENTAL GOAL OF THIS VISION IS TO ADVANCE U.S. SCIENTIFIC, SECURITY, AND ECONOMIC INTEREST THROUGH A ROBUST SPACE EXPLORATION PROGRAM



Implement a sustained and affordable human and robotic program to explore the solar system and beyond

Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;

Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and

Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

- "**Develop a new crew exploration vehicle** to provide crew transportation for missions beyond low Earth orbit"
- "**Separate to the maximum practical extent crew from cargo transportation** to the International Space Station and for launching exploration missions beyond low Earth orbit (LEO)"
- "**Develop and demonstrate power generation, propulsion...and other key capabilities** required to support more distant, more capable, and/or longer duration human and robotic exploration of Mars and other destinations"

Policy Context (cont'd)

U.S. Space Transportation Policy (December 2004)

THE FUNDAMENTAL GOAL OF THIS POLICY IS TO ENSURE THE CAPABILITY TO ACCESS AND USE SPACE IN SUPPORT OF NATIONAL AND HOMELAND SECURITY, CIVIL, SCIENTIFIC, AND ECONOMIC INTERESTS.

The United States Government shall:

- **Ensure the availability of U.S. space transportation capabilities necessary to provide reliable and affordable space access, including access to, transport through, and return from space**
- **Demonstrate an initial capability for operationally responsive access to and use of space**
- **Develop space transportation capabilities to enable human space exploration beyond LEO**
  - NASA to engage in development activities only for those requirements that cannot be met by capabilities being used by the national security or commercial sectors
  - "For the foreseeable future", Evolved Expendable Launch Vehicle (EELV) capabilities shall be the foundation for access to space for intermediate and larger payloads for national/homeland security and civil purposes
  - NASA and DOD to develop options to meet exploration-unique requirements for heavy lift beyond the capabilities of existing EELVs (e.g. EELV derivative, Shuttle derivative, or new dedicated vehicle)
- **Sustain a focused technology development program for next-generation space transportation capabilities**
  - Requirements, concept of operations, technology roadmaps, and investment strategy within 2 years
  - In-space transportation R&D (e.g. automated rendezvous/docking, spacecraft deployment/servicing/retrieval, and space nuclear power/propulsion)
- **Encourage and facilitate the U.S. commercial space transportation industry**
- **Sustain and promote a domestic space transportation industrial base**

NASA Space Transportation Programs

Exploration Systems Mission Directorate

- Constellation Systems
  - Transportation Systems (e.g. Crew Exploration Vehicle)
  - In-Space and Planetary Surface Systems
  - Transition Programs (e.g. Next Generation Launch Tech., Demo of Autonomous Rndz Technology)
- **Exploration Systems Research & Technology (ESR&T)**
  - **Advanced Space Technology**
  - **Technology Maturation**
  - **Innovative Partnerships**

(Focus of this briefing)

- Prometheus Nuclear Systems & Technology
  - Nuclear Propulsion for Jupiter Icy Moons Orbiter (JIMO) Mission

Space Operations Mission Directorate

- Space Shuttle Program
  - Return-to-Flight Effort (STS-114 mission targeted for launch opportunity May 2005)

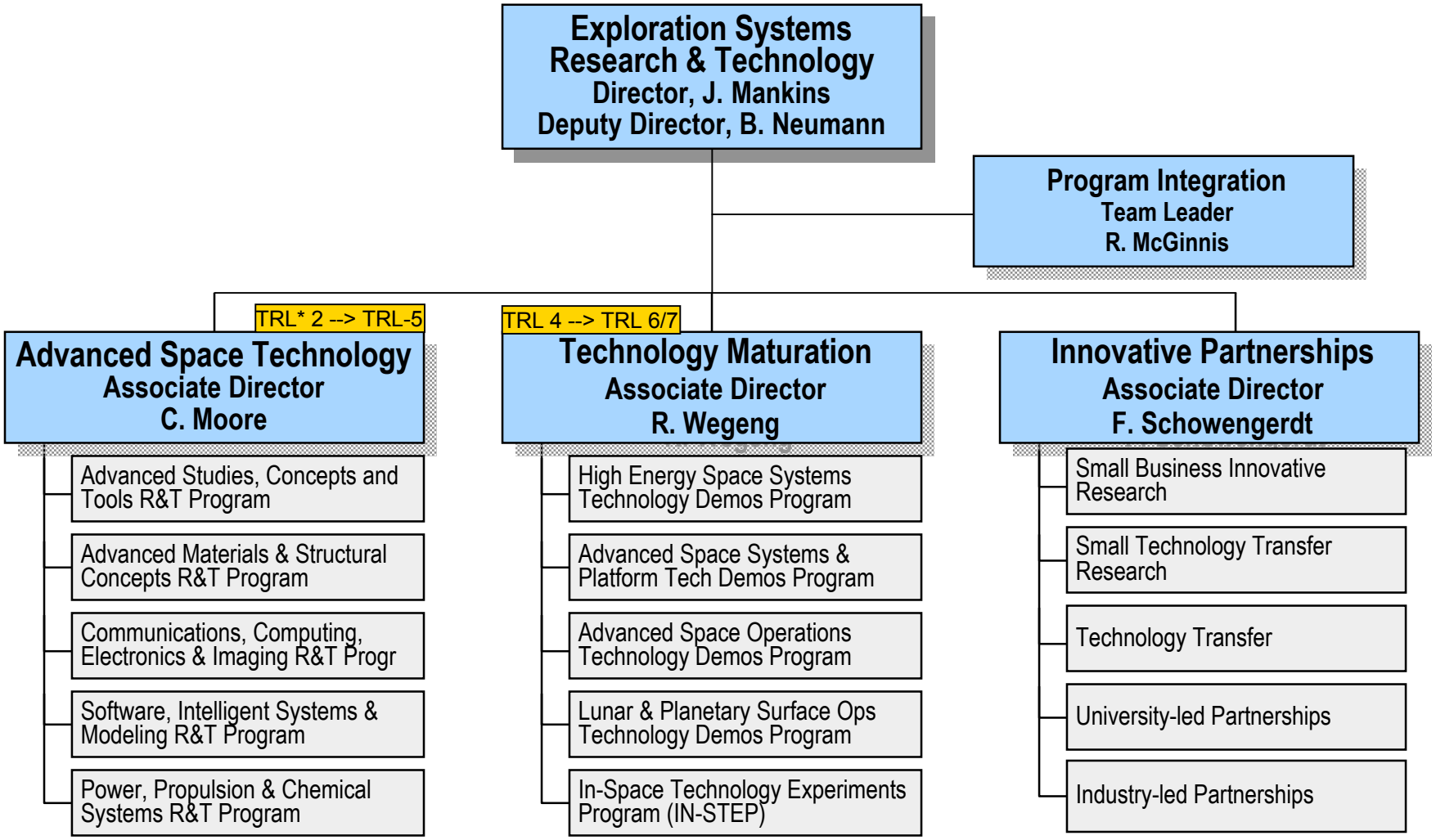
Science Mission Directorate

- In-Space Power and Propulsion Program (e.g. Ion propulsion, aero-assist, solar sails, tethers)

Aeronautics Research Mission Directorate

- No space transportation programs in FY 2005
- Potential Future Work
  - Hypersonic air-breathing propulsion (Hyper-X/X-43A scramjet program concluded in 2004)
  - Unpiloted Air Vehicles for planetary flight

Exploration Systems Research and Technology
Organization



* TRL = Technology Readiness Level

Technology Investment Drivers

ESR&T Goals Derived from the Vision for Space Exploration

***ESR&T GOAL**: Provide the critical foundation of knowledge and validated technologies for achieving the Vision for Space Exploration, while delivering technologies of broad common value to NASA, the Nation and the U.S. economy.*

Sustainable
Vision for Space Exploration

Affordable
Systems & Operations (Development, Ownership, Missions)

Reliable/Safe
*Systems & Operations ASARA**

Effective
Missions & Systems

Flexible
Robust in terms of Policy, Adaptive to Events

STRATEGIC TECHNICAL CHALLENGES

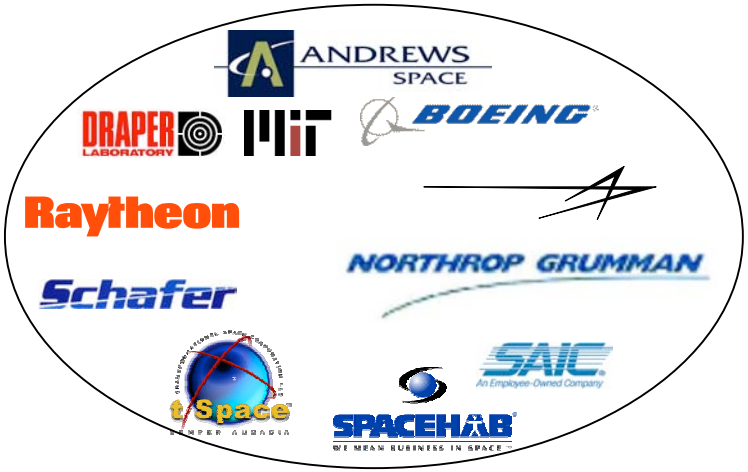
Margins and Redundancy	**Modularity**	**Energy-Rich** Systems and Missions	**In-Space Assembly**
Autonomy	**Reusability**	**Data-Rich Virtual Presence**	**Re-configurability** (H/W, S/W, Systems)
Human Presence in Deep Space (ASARA)	**Robotic Networks**	**Space Resources Utilization**	**Affordable Pre-Positioning of Logistics**
Timely Science Achievements	**Access to Surface Targets** Precise, Repeatable	**Low-Cost Cargo Launch**	**Reliable Crew Launch**

ASARA - "As safe as reasonably achievable"

Technology Investment Drivers

Technology Needs Identified by CE&R Contractors *

- **Heavy Lift Launch**
- **In-space Cryogenic Propulsion**
  - Throttleable, highly reliable, reusable
- **In-Space Cryogenic fluid management / transfer**
  - Long-term Low/Zero Boil-off
- **In-Situ Resource Utilization for propellant production**
- **High-Power Solar Electric propulsion**
  - High specific impulse, long-life
- **Autonomous rendezvous and docking**
- **Integrated Vehicle/System Health Management**
- **Aeroassist/Thermal Protection System technology**
  - Human-rated, lightweight, reusable, active/passive
- **Precision landing**
- **Surface mobility with open and pressurized rovers**



*** Results of Technical Interchange Meeting with Concept Evaluation & Refinement (CE&R) Contractors, December 2004**

Technology Investment Drivers

Preliminary NASA Exploration Requirements (1 of 2)

- **Agency Level 0 Exploration Requirements**
  (Office of the Administrator / May 2004)

- **Exploration System of Systems Requirements (Rev D)**
  (Exploration Systems Mission Directorate Requirements Division / Jan 2005)
  - **Crew Transportation System**
    - Crew Exploration Vehicle, CEV Launch Vehicle, Lunar Surface Access Module
  - **Cargo Delivery System**
    - Cargo Launch Vehicle, Earth Departure Stage
  - **Robotic Precursor System**
  - **Destination Surface system**
    - Surface Transportation Systems

Technology Investment Drivers

Preliminary NASA Exploration Requirements (2 of 2)

ESR&T Coverage of ESMD Requirements Division-Identified Technology Needs

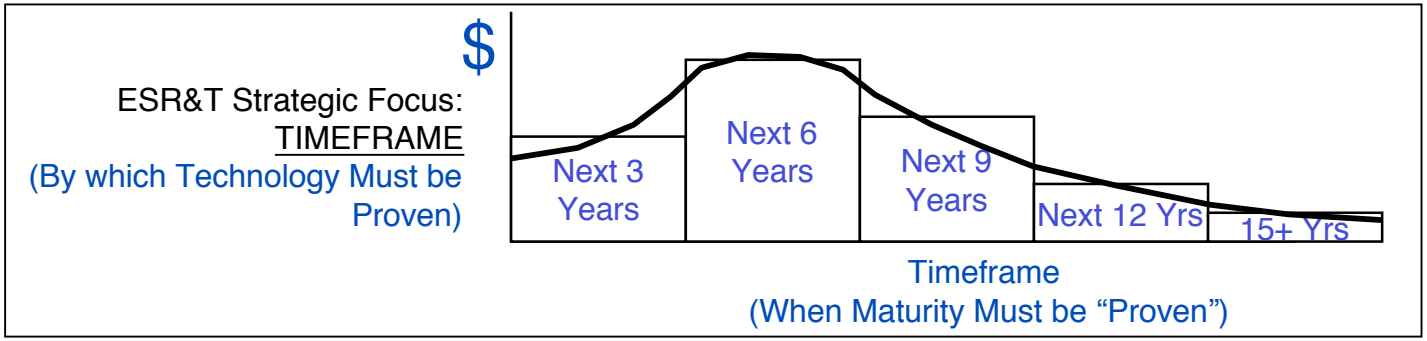
	ASTP					TMP					IPP
	Advanced Studies, Concepts And Tools Program*	Advanced Materials and Structural Concepts Program	Communications, Computing, Electronics & Imaging Program	Software, Intelligent Systems & Modeling Program	Power, Propulsion & Chemical Systems Program	High Energy Systems Technology Program	Space Platforms and Systems Technology Program	Space Operations Technology Program	Lunar and Planetary Surface Operations Technology Program	In-Space Technology Experiments Program	IPP Summary (SBIR, STTR, TTA, URETIs, RPC's)
Requirement Division Identified Technologies											
Human Support											
Radiation Protection	✓	✓	✓						✓	✓	✓
Medical Care	✓									✓	✓
Life Support System Closure	✓									✓	✓
Human -System Design	✓		✓	✓						✓	✓
In-Space Transportation											
Advanced Chemical Propulsion	✓				✓	✓				✓	✓
Electric Propulsion	✓				✓					✓	✓
Nuclear Thermal Propulsion	✓									✓	✓
Cryogenic Fluid Management	✓	✓			✓	✓				✓	✓
Aeroassist	✓	✓			✓	✓				✓	✓
Automated Rendezvous and Docking	✓	✓	✓				✓	✓		✓	✓
Power											
Power Generation (Solar)	✓				✓	✓				✓	✓
Power Generation (Nuclear)	✓									✓	✓
Mobile Power (Advanced Batteries)	✓				✓				✓	✓	✓
Mobile Power (Fuel Cells)	✓				✓				✓	✓	✓
Mobile Power (Radioisotopes)	✓									✓	✓
Energy Storage	✓				✓					✓	✓
Power Distribution	✓			✓	✓	✓	✓			✓	✓
Miscellaneous and Crosscutting Technologies											
Sensors and Instruments	✓	✓	✓							✓	✓
In-Situ Resource Utilization	✓	✓	✓		✓				✓	✓	✓
Advanced Materials	✓	✓								✓	✓
Thermal Management	✓	✓			✓	✓				✓	✓
Advanced Habitation	✓	✓					✓			✓	✓
Advanced EVA	✓	✓	✓	✓				✓		✓	✓
Robotic Human Support	✓		✓	✓				✓	✓	✓	✓
On-Board Computing	✓		✓				✓	✓		✓	✓
Simulation-based Design and Analysis	✓		✓	✓				✓		✓	✓
Communications	✓		✓				✓			✓	✓
Supportability	✓		✓				✓	✓	✓	✓	✓

Exploration Systems Research & Technology
Investment Strategy

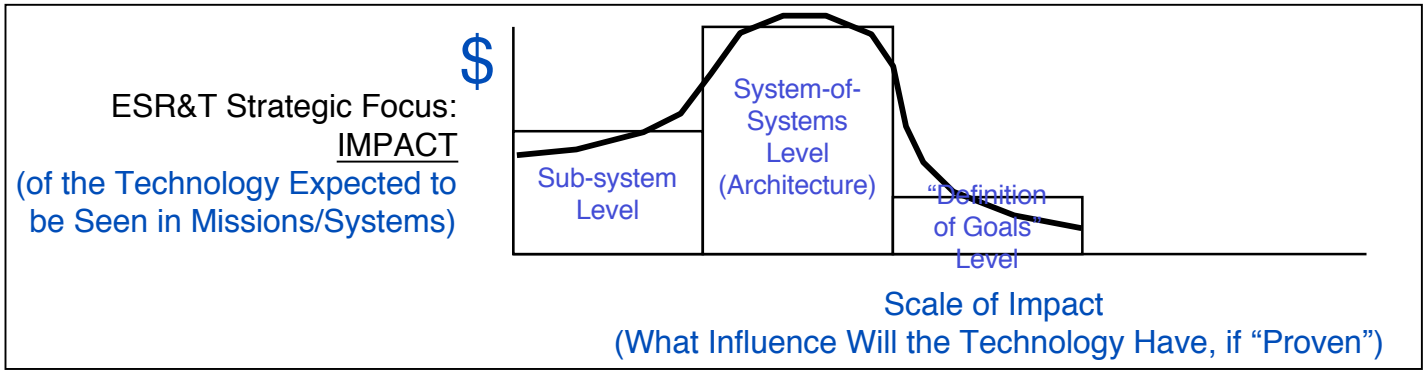
- **Integrated / Coordinated Investments**
  - Ongoing ESMD Strategy-to-Task-to-Technology Process
    (in concert with Requirements Division, Constellation Systems, CE&R Contractors)
  - NASA-wide Technology Development Coordination Group
  - Integration with U.S. Government Departments / Agencies
  - Coordination with Industry Internal Research and Development (IRAD)
  - University Partnerships
  - International Coordination

- **Competitive Selection of Projects**

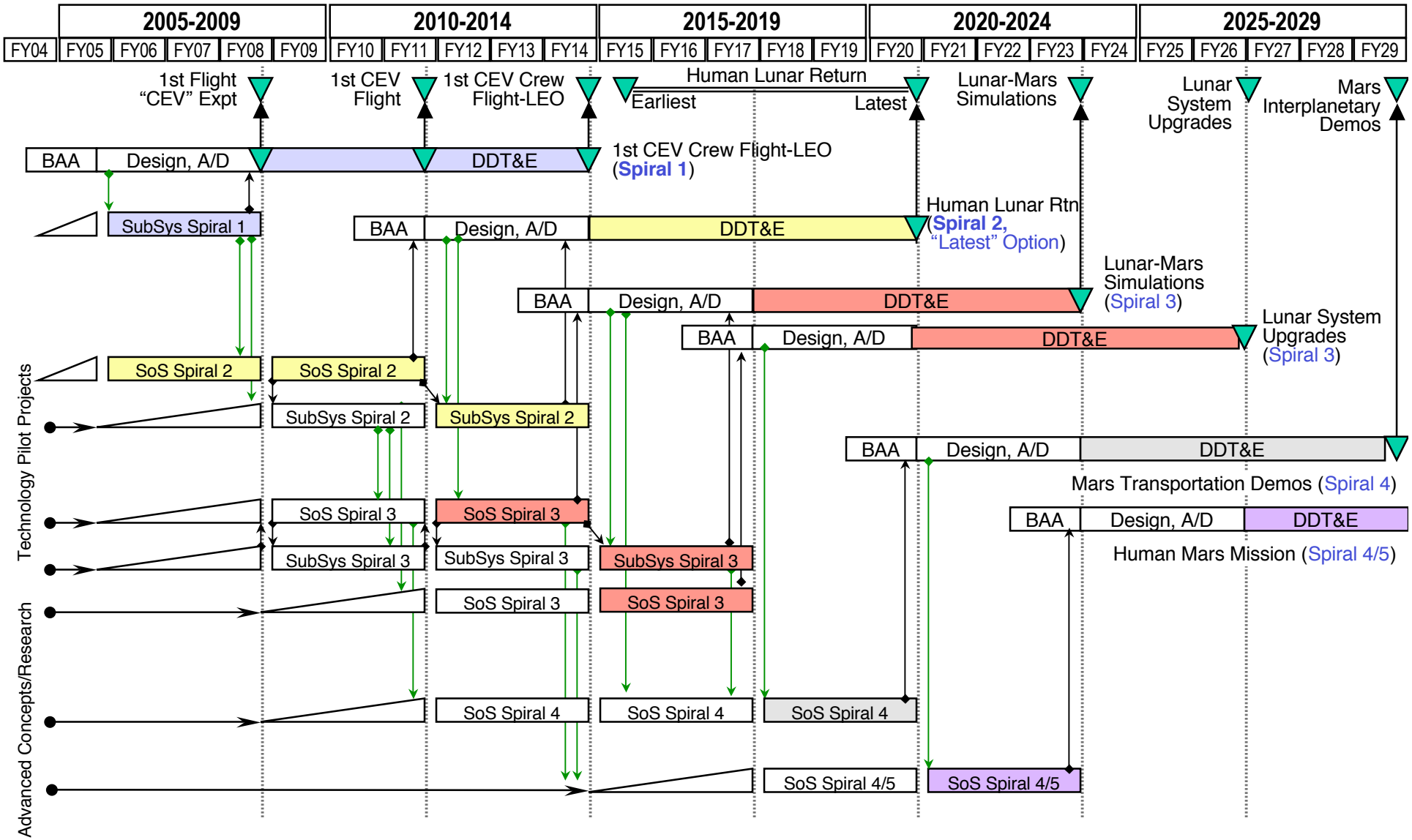
- **Balanced Portfolio**
  - Low/High Risk
  - Near-term/ Far-term:



  - Broad/ focused Impact:



Phased Technology Infusion into Exploration Spirals



BAA = Broad Agency Announcement
DDT&E = Design, Development, Test & Eng.
A/D = Advanced Development

SubSys = Sub-System Level-Impact Technology
SoS = System-of-System Level-Impact Technology

ESR&T Technology Investment Status

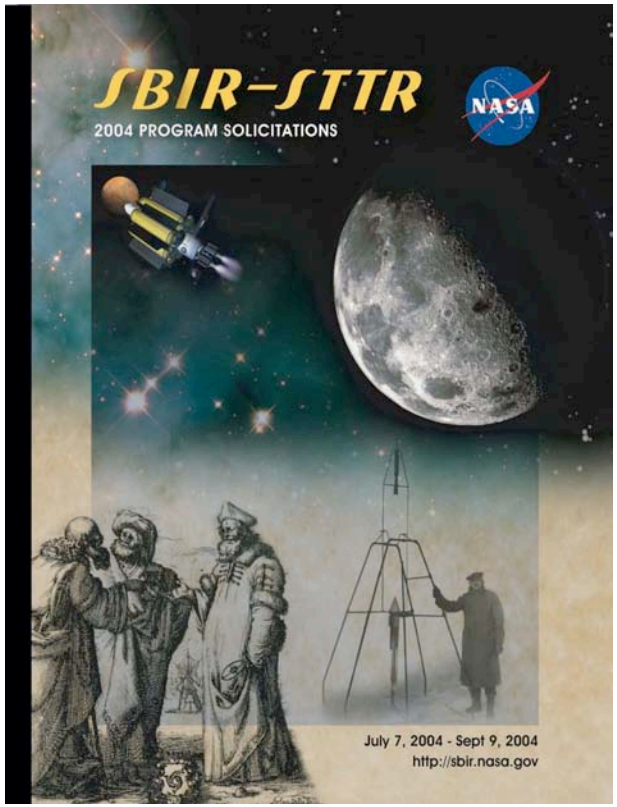
Sample ASTP/TMP Projects related to Space Transportation

Technology Area	Project Title
Heavy Lift Launch	• Friction Stir Welding of Thin Sheet Alloys to Create Affordable Ultra-lightweight Cryo Tanks (ASTP) • Thermal Protection System & Heat Resistant Structures (TMP)
In-space Cryogenic Propulsion	• Variable Thrust Pintle Descent/Ascent Engine (ASTP) • Deep Throttling Common Extensible Cryogenic Engine (TMP)
In-Space Cryogenic fluid management / transfer	• Long-Life Lightweight Oxidation-Resistant Cryogen Tank (ASTP) • In-Space Cryogenic Propellant Depot (TMP)
ISRU for propellant production	• Microchannel In Situ Propellant Production System (ASTP) • Integrated ISRU for Human Exploration Propellant Production for the Moon and Beyond (TMP)
High-Power Solar Electric Propulsion	• MW-Class MPD Electric Propulsion System Demonstration (ASTP) • Ultra-High Specific Power Density Solar Blanket (ASTP) • 600-Kw High Thrust Hall Thruster System (TMP) • Solar Electric Propulsion Direct Drive Demonstrator (TMP)
Autonomous rendezvous/docking	• A Plug-and-Play Architecture for Real-Time Intelligent Avionics (ASTP) • Advanced Docking/Berthing System for Rendezvous Operations and In-Space Assembly (TMP)
Integrated Vehicle/System Health Management	• Decision Support System for Health Management (ASTP) • Integrated System Health Management Testbed and Prototypes (TMP)
Aeroassist/Thermal Protection System technology	• Aero-Assist Mars Transfer Vehicle System Technology Design (ASTP) • Ultralightweight Inflatable Ballutes for Return to Earth from the Moon (ASTP) • Deployable Skirt System for Aero-assist Systems (TMP)
Precision landing	• Laser/Lidar Technologies for Exploration (ASTP) • Precision Landing and Hazard Avoidance Technology Demonstration (TMP)
Surface mobility w/ open and pressurized rovers	• Advanced Electrochemical Energy Storage Systems for Robotic/Human Exploration Missions (ASTP) • Rough and Steep Terrain Lunar Surface Mobility (TMP)

ASTP = Advanced Space Technology Program TMP = Technology Maturation Program

ESR&T Technology Investment Status

Innovative Partnerships Program



Annual Value: ~$117M

FY'05-'08 Value: ~$500M

- **SBIR/STTR…sometimes a neglected investment portfolio**
- **ESR&T includes NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs**
  - Addresses technology needs of ESMD, as well as other Mission Directorates across NASA
- **New processes established to better align future SBIR/STTR projects with strategically-focused needs of ESMD (and other MDs)**
- **Analysis of recent FY'04 Phase 2 results against ESR&T (ASTP/TMP) underway to enable alignment of projects with Element Programs**
- **New process used for upcoming Phase 2 selections-Strong Mission Directorate Involvement**
- **Increased focus/alignment planned for FY 2006 RFP**

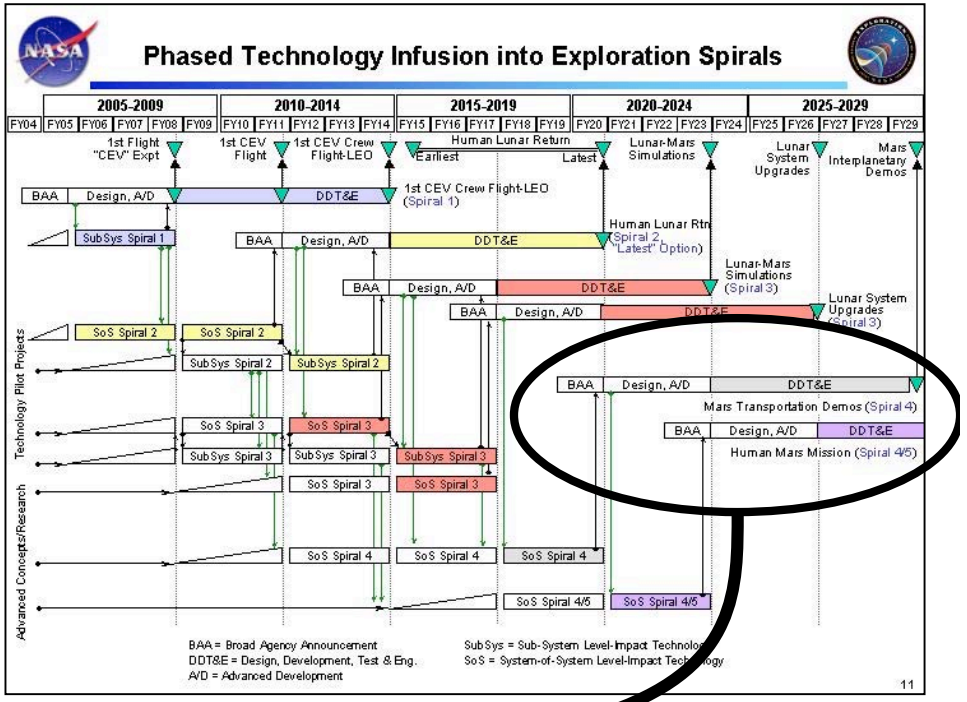
Exploration Systems Research & Technology

Future Directions

Critical Long-Term Issues

Meeting key Strategic Technical Challenges to enable an affordable, reliable/safe, effective, flexible space exploration campaign

- **In-Space Transportation for Human Exploration of Mars and Beyond**
  (Human Presence in Deep Space)
- **Earth-to-Orbit Transportation for Human Exploration of Mars and Beyond**
  (Low-Cost Cargo Launch, Reliable Crew Launch)
- **Launch Infrastructure Throughput**
  (Margins and Redundancy)
- **Affordable, Robust Aeroassist Systems for Earth and Mars**
  (Access to Surface targets, Affordable Pre-Positioning of Logistics)
- **In-Space Propellant Supply**
  (Reusability, Space Resources Utilization, Affordable Pre-Positioning of Logistics)
- **Autonomous Rendezvous and Docking Systems**
  (Modularity, Reconfigurability, Autonomy, In-Space Assembly)



Exploration Systems Research & Technology
FY05 Plans in Support of Space Transportation

- **Capability Gaps Being Identified for Spiral 1**
  - Integrated Vehicle Health Management
  - Thermal protection systems
- **Investment Strategy Established to Fund Technologies that:**
  - Fills Gaps and Improves Affordability by focusing on “System of System” Improvements such as Reusability, Reliability, System Effectiveness…
  - Emphasizes technologies of broad potential value
  - Relies on competitive selection of projects through internal/external solicitations
- **End-to-End Program Reformulation to Support Exploration Vision**
  - First ESR&T Intramural Call for Proposals (ICP) – projects initiated Jan 2004
  - First ESR&T Broad Agency Announcement (BAA) – contracts to be negotiated by April 2005
  - Plan follow-on Intramural Process to address capability gaps
  - Plan Second BAA to infuse needed new technologies in Constellation Systems Spiral I (includes CEV)
- **Plan to establish more rigorous Strategy-to-Task-to-Technology Process**